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Development and Qualification Status of the CMC based TPS of Space Rider

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Abstract

Space Rider is an unmanned space robotic laboratory. After launch it will stay in orbit for about two months and then it will return to Earth with its payloads and land on ground. It can be recovered, reconfigured and reused for up to six missions. Such kind of spacecraft, designed to safely came back to Earth, are characterized by Thermal Protection System (TPS) necessary to protect the vehicle from the typical harsh environment encountered during atmospheric re-entry phase, keeping unchanged the vehicle outer mold line. Further, when precise landing is required, hot control surfaces allowing maneuvers are mandatory. The present paper summarizes the status of the testing activities for the sub-system qualification.

Keywords: *Re-entry, re-usability, TPS, CMC.*

Nomenclature

Latin	
BFA	Body Flap Assembly
CMC	computational fluid dynamics
ESA	European Space Agency
IXV	Intermediate Experimental Vehicle
LSI	Liquid Silicon Infiltration
SR	Space Rider
TPS	Thermal Protection System

1. Introduction

CIRA and Petroceramics are presently in charge of design, manufacturing and qualification of the CMC TPS and Body Flaps Assembly of Space Rider, thanks to the development of a proprietary C/SiC, named ISiComp®, based on LSI process with shorter manufacturing times and using low cost raw materials, leading to a very cost-efficient CMC.

Building on lessons learnt from the successful IXV [1] re-entry demonstration, Space Rider TPS and Hot Structure design has been focused on reducing manufacturing complexity while improving easiness of integration that in turns allows for faster post flight inspection and refurbishment. The program is sunning in its phase D. Highlights on development and qualification testing activities will be shown.

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2. TPS & BFA Development Test

Attachment Mechanical Tests

In order to assess the mechanical strength of the designed mechanical connections between the shingles and the underneath cold structure, three different load conditions (tensile, shear-X and shear-Y) have been investigated.

For each test condition, two different types of test have been performed:

1. failure test, to quantify the maximum load carrying capability of the component: the ultimate load;
2. life cycle test, to assess reusability of the component for six re-entry flight.

In life cycle tests, the same test has been repeated six times on the same test article. Moreover, at the end of the last load cycle a failure test is performed on the same test article.

Experimental results highlight that the ultimate loads for all load cases are always higher than the operative loads ensuring the mechanical capability proof of the joint.

Fig 2. Tensile test and shear Y set-ups

Fig 3. Tensile test and shear Y set-ups

In addition to the mechanical capability proof, have been successfully verified also the single mission and the reusability capability proofs. Furthermore, experimental ultimate strengths are in line with numerical predictions and no significant reductions are observed after life cycle tests.

Insulation Stack-up Tests

The purpose of these tests is to validate thermal model of the identified insulation stack-up materials.

Thermal test considering the CMC Panel and the different layers of insulation, including a sample of the cold structure, will be tested at representative flight conditions of both re-entry (HT) and orbital phase (LT). The test article is instrumented with thermocouples located at different depth of the stack-up. For HT tests a dedicated furnace have been realized to guarantee a max temperature on CMC up to 1600°C and keeping the lateral side as much adiabatic is possible. Test campaign is on-going.

Metallic Attachment Tests

The purpose of these tests is to verify the mechanical strength of the designed metallic connections between:

- CMC Nose Omega and the metallic ring;
- CMC Windward Omega and Leg and the Cold Structure.

The mechanical connections at room and high temperature between the CMC components and the metallic structure shall be tested by means of dedicated breadboards.

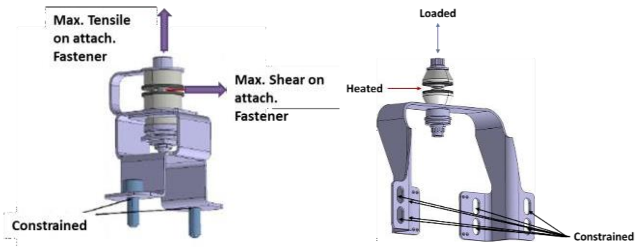

Fig 4. Windward & Nose attachments to be tested

BFA Attachment Bearing Breadboards Loaded Tests

The purpose of these tests has been to verify the capabilities of the designed mechanical connections between the CMC flap and the metallic structure to operate properly under thermal and mechanical loads. The experimental set-up (see Fig 17) included an ad-hoc designed furnace to heat the breadboard (representative of the actuator/flap hinge) meanwhile the mechanical load is applied. A maximum load of 18 kN and 540°C temperature have been applied. Six cyclic loads, as for SR reusability plan, were successfully performed.

3. TPS & BFA Qualification Status

3.1. QM Manufacturing

All the manufacturing demonstrators have been completed and the qualification models manufacturing is on going and the beginning of the qualification test on both TPS and BFA is foreseen by the beginning of next year.

Fig 1. Manufacturing Demonstrator (EMs)

4. Testing Preparatory Activities

A complete Nose Assembly, a representative sub-set of Windward Shingles, a complete port side Hinge TPS Assembly and a complete Body Flap Port Assembly, composed by CMC parts, insulation stack-up and attachments will be subjected to the following test sequence:

- Integration Test
- Modal Test
- Sine Vibration Test
- Random Acoustic Test
- Shock Test
- Static Test
- Kinematic Test (Only for BFA)
- Thermomechanical Test
- Plasma Wind Tunnel Test (only for Shingle and BFA with dedicated sub-scale test article)

The facilities have been selected, the test fixtures design and their manufacturing almost completed. Test specifications were consolidated and the test campaign will start at the beginning of next year.

5. Conclusion

An overall picture of the status of development and qualification of the Space Rider Thermal Protection System will be provided

An extensive development activity has been performed and the qualification program is currently on-going. Qualification units of all main assemblies are under manufacturing and the qualification test campaign is ready to start by the beginning of next 2024.

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